METHODS OF TREATING DIABETES BY BLOCKING VEGF-MEDIATED ACTIVITY

Cross-Reference to Related Applications

[0001] This application claims the benefit under 35 USC § 119(e) of U.S. Provisional 60/458,790 filed 28 March 2003, which application is herein specifically incorporated by reference in its entirety.

BACKGROUND

Field of the Invention

[0002] The field of the invention is generally related to methods of treating diabetes by administering agents capable of decreasing serum glucose levels. In particular, the field of the invention is methods of treating diabetes by administering agents capable of blocking, inhibiting, or ameliorating VEGF-mediated activity.

Description of Related Art

[0003] It has been reported that *db/db* mice, a murine model of type 2 diabetes, treated with an antibody against VEGF show amelioration of diabetic renal changes, but do not exhibit a decrease in body weight, serum glucose levels, insulin levels or food consumption (Flyvbjerg et al. (2002) Diabetes 51:3090-3094).

BRIEF SUMMARY OF THE INVENTION

[0004] In a first aspect, the invention features a method of treating diabetes comprising administering to a mammal an agent capable of blocking, inhibiting, or ameliorating VEGF-mediated activity. In specific embodiments, the method of treatment of the invention results in decreased serum glucose levels, improved glucose tolerance, improved insulin sensitivity, reduced hyperinsulinemia, and/or improved glycemic control.

[0005] In a specific embodiment, the diabetes treated is Type 2 diabetes (also termed non-insulin dependent diabetes mellitus) (NIDDM). In specific conditions, Type I diabetes or gestational diabetes may also be treated.

[0006] The agent capable of blocking, inhibiting, or ameliorating VEGF-mediated activity in specific embodiments is a VEGF antagonist. More specifically, the VEGF antagonist includes a

VEGF trap selected from the group consisting of acetylated Flt-1(1-3)-Fc, Flt-1(1-$3_{R->N}$)-Fc, Flt-1(1-$3_{\Delta B}$)-Fc, Flt-1(2-$3_{\Delta B}$)-Fc, Flt-1(2-3)-Fc, Flt-1D2-VEGFR3D3-FcΔC1(a), Flt-1D2-Flk-1D3-FcΔC1(a), and VEGFR1R2-FcΔC1(a). In other specific embodiments, the agent is an antibody, lipid, nucleic acid, small molecule, aptamer, antisense molecule, carbohydrate, peptidomimetic, or hapten.

[0007] Administration of the agent may be by any method known in the art, including subcutaneous, intramuscular, intradermal, intraperitoneal, intravenous, intranasal, or oral routes of administration.

[0008] The mammal treated is preferably a human subject suffering from diabetes. Also suitable for treatment by the method of the invention is a subject at risk for development of type 2 diabetes who exhibits one or more symptoms of type 2 diabetes or of a condition associated with the development of type 2 diabetes, such as, for example, such as insulin resistance, dyslipidemia, polycystic ovarian syndrome, obesity, hyperglycemia, hyperlipidemia, hypercholesteremia, hypertriglyceridemia, hyperinsulinemia, and hypertension.

[0009] In a second aspect, the invention features a method of inhibiting or slowing the progression of type 2 diabetes in a mammal, comprising administering to a mammal an agent capable of blocking or inhibiting VEGF-mediated activity.

[0010] In a third aspect, the invention features a method of improving glucose tolerance or insulin sensitivity in a mammal in need thereof, comprising administering to a mammal an agent capable of blocking or inhibiting VEGF-mediated activity.

[0011] Other objects and advantages will become apparent from a review of the ensuing detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0012] Figs. 1A-B: (A) Serum glucose levels and (B) body weight at 4 weeks in diabetic *(db/db)* and non-diabetic *(db/?)* mice treated with VEGFR1R2-FcΔC1(a).

[0013] Fig. 2: Serum glucose levels through 8 weeks of treatment of controls and treated diabetic *(db/db)* and non-diabetic *(db/?)* mice with VEGFR1R2-FcΔC1(a)..

[0014] Fig. 3: Oral glucose tolerance test at 4 weeks of treatment for control and VEGFR1R2-FcΔC1(a)-treated diabetic *(db/db)* mice and non-diabetic *(db/?)* mice.

[0015] Fig. 4: Oral glucose tolerance test at 8 weeks of treatment for control and VEGFR1R2-FcΔC1(a)-treated diabetic *(db/db)* mice and non-diabetic *(db/?)* mice.

[0016] Fig. 5A-B Fasting serum glucose and insulin levels after 8 weeks of treatment of control and VEGFR1R2-FcΔC1(a)-treated diabetic *(db/db)* mice and non-diabetic *(db/?)* mice.

DETAILED DESCRIPTION

[0017] Before the present methods are described, it is to be understood that this invention is not limited to particular methods, and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only the appended claims.

[0018] As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Thus for example, a reference to "a method" includes one or more methods, and/or steps of the type described herein and/or which will become apparent to those persons skilled in the art upon reading this disclosure and so forth.

[0019] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described. All publications mentioned herein are incorporated herein by reference in their entirety.

General Description

[0020] The invention is based in part on the finding that administration of an agent capable of blocking or inhibiting VEGF-mediated activity is capable of decreasing serum glucose and improving glucose disposal in diabetic mammals. These findings represent the first time an agent capable of blocking or inhibiting VEGF-mediated activity has been shown to ameliorate diabetes. Thus, the invention provides for methods of treating diabetes in a mammal by administering a VEGF antagonist. More specifically, the method of the invention may be practiced with a VEGF antagonist such as a VEGF trap, as shown below, or a VEGF-specific antibody.

Definitions

[0021] By the term "therapeutically effective dose" is meant a dose that produces the desired effect for which it is administered. The exact dose will depend on the purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques (see, for example, Lloyd (1999) The Art, Science and Technology of Pharmaceutical Compounding).

[0022] By the term "blocker", "inhibitor", or "antagonist" is meant a substance that retards or

prevents a chemical or physiological reaction or response. Common blockers or inhibitors include but are not limited to antisense molecules, antibodies, antagonists and their derivatives. More specifically, an example of a VEGF blocker or inhibitor is a VEGF receptor-based antagonist including, for example, an anti-VEGF antibody, or a VEGF trap such as VEGFR1R2-FcΔC1(a) (SEQ ID NOs:1-2). For a complete description of VEGF-receptor based antagonists including VEGFR1R2-FcΔC1(a), see PCT publication WO/00/75319, the contents of which is incorporated in its entirety herein by reference.

[0023] A "small molecule" is defined herein to have a molecular weight below about 500 Daltons, and may include chemical as well as peptide molecules.

Nucleic Acid Constructs

[0024] Individual components of the VEGF-specific fusion proteins of the invention may be constructed by molecular biological methods known to the art with the instructions provided by the instant specification. These components are selected from a first cellular receptor protein, such as, for example, VEGFR1; a second cellular receptor protein, such as, for example, VEGFR2; a multimerizing component, such as an Fc.

[0025] Specific embodiments of the VEGF-specific fusion proteins useful in the methods of the invention comprise a multimerizing component which allows the fusion proteins to associate, e.g., as multimers, preferably dimers. Preferably, the multimerizing component comprises an immunoglobulin derived domain. Suitable multimerizing components are sequences encoding an immunoglobulin heavy chain hinge region (Takahashi et al. 1982 Cell 29:671-679); immunoglobulin gene sequences, and portions thereof.

[0026] The nucleic acid constructs encoding the fusion proteins useful in the methods of the invention are inserted into an expression vector by methods known to the art, wherein the nucleic acid molecule is operatively linked to an expression control sequence. Host-vector systems for the production of proteins comprising an expression vector introduced into a host cell suitable for expression of the protein are known in the art. The suitable host cell may be a bacterial cell such as *E. coli*, a yeast cell, such as *Pichia pastoris,* an insect cell, such as *Spodoptera frugiperda*, or a mammalian cell, such as a COS, CHO, 293, BHK or NS0 cell.

Antisense Nucleic Acids

[0027] In one aspect of the invention, VEGF-mediated activity is blocked or inhibited by the use of

VEGF antisense nucleic acids. The present invention provides the therapeutic or prophylactic use of nucleic acids comprising at least six nucleotides that are antisense to a gene or cDNA encoding VEGF or a portion thereof. As used herein, a VEGF "antisense" nucleic acid refers to a nucleic acid capable of hybridizing by virtue of some sequence complementarity to a portion of an RNA (preferably mRNA) encoding VEGF. The antisense nucleic acid may be complementary to a coding and/or noncoding region of an mRNA encoding VEGF. Such antisense nucleic acids have utility as compounds that prevent VEGF expression, and can be used in the treatment of diabetes. The antisense nucleic acids of the invention are double-stranded or single-stranded oligonucleotides, RNA or DNA or a modification or derivative thereof, and can be directly administered to a cell or produced intracellularly by transcription of exogenous, introduced sequences.

[0028] The VEGF antisense nucleic acids are of at least six nucleotides and are preferably oligonucleotides ranging from 6 to about 50 oligonucleotides. In specific aspects, the oligonucleotide is at least 10 nucleotides, at least 15 nucleotides, at least 100 nucleotides, or at least 200 nucleotides. The oligonucleotides can be DNA or RNA or chimeric mixtures or derivatives or modified versions thereof and can be single-stranded or double-stranded. In addition, the antisense molecules may be polymers that are nucleic acid mimics, such as PNA, morpholino oligos, and LNA. Other types of antisence molecules include short double-stranded RNAs, known as siRNAs, and short hairpin RNAs, and long dsRNA (>50 bp but usually ≥500 bp).

Inhibitory Ribozymes

[0029] In aspect of the invention, diabetes may be treated in a subject suffering from such disease by decreasing the level of VEGF activity by using ribozyme molecules designed to catalytically cleave gene mRNA transcripts encoding VEGF, preventing translation of target gene mRNA and, therefore, expression of the gene product.

[0030] Ribozymes are enzymatic RNA molecules capable of catalyzing the specific cleavage of RNA. The mechanism of ribozyme action involves sequence-specific hybridization of the ribozyme molecule to complementary target RNA, followed by an endonucleolytic cleavage event. The composition of ribozyme molecules must include one or more sequences complementary to the target gene mRNA, and must include the well known catalytic sequence responsible for mRNA cleavage. For this sequence, see, *e.g.*, U.S. Patent No. 5,093,246. While ribozymes that cleave mRNA at site-specific recognition sequences can be used to destroy mRNAs encoding VEGF, the use of hammerhead ribozymes is preferred. Hammerhead ribozymes cleave mRNAs at locations

dictated by flanking regions that form complementary base pairs with the target mRNA. The sole requirement is that the target mRNA has the following sequence of two bases: 5'-UG-3'. The construction and production of hammerhead ribozymes is well known in the art. The ribozymes of the present invention also include RNA endoribonucleases (hereinafter "Cech-type ribozymes") such as the one that occurs naturally in *Tetrahymena thermophila* (known as the IVS, or L-19 IVS RNA). The Cech-type ribozymes have an eight base pair active site that hybridizes to a target RNA sequence where after cleavage of the target RNA takes place. The invention encompasses those Cech-type ribozymes that target eight base-pair active site sequences that are present in the gene encoding VEGF.

Generation of Antibodies to VEGF Proteins

[0031] In another aspect of the invention, the invention may be practiced with an anti-VEGF antibody or antibody fragment capable of binding and blocking VEGF activity. Anti-VEGF antibodies are disclosed, for example, in US Patent No. 6,121,230, herein specifically incorporated by reference. The term "antibody" as used herein refers to a polypeptide comprising a framework region from an immunoglobulin gene or fragments thereof that specifically binds and recognizes an antigen. The recognized immunoglobulin genes include the kappa, lambda , alpha, gamma, delta, epsilon, and mu constant regions, as well as the myriad immunoglobulin variable region genes. Light chains are classified as either kappa or lambda. Heavy chains are classified as gamma, mu, alpha, delta, or epsilon, which in turn define the immunoglobulin classes, IgG, IgM, IgA, IgD, and IgE, respectively. Within each IgG class, there are different isotypes (eg. IgG_1, IgG_2, etc.). Typically, the antigen-binding region of an antibody will be the most critical in determining specificity and affinity of binding.

[0032] Antibodies exist as intact immunoglobulins, or as a number of well-characterized fragments produced by digestion with various peptidases. For example, pepsin digests an antibody below the disulfide linkages in the hinge region to produce $F(ab)'_2$, a dimer of Fab which itself is a light chain joined to V_H-C_H1 by a disulfide bond. The $F(ab)'_2$ may be reduced under mild conditions to break the disulfide linkage in the hinge region, thereby converting the $F(ab)'_2$ dimer into an Fab' monomer. The Fab' monomer is essentially Fab with part of the hinge region. While various antibody fragments are defined in terms of the digestion of an intact antibody, one of skill will appreciate that such fragments may be synthesized *de novo* either chemically or by using recombinant DNA methodology. Thus, the terms antibody, as used herein, also includes antibody

fragments either produced by the modification of whole antibodies, or those synthesized *de novo* using recombinant DNA methodologies (e.g., single chain Fv)(scFv) or those identified using phase display libraries (see, for example, McCafferty et al. (1990) Nature 348:552-554).

[0033] Methods for preparing antibodies are known to the art. See, for example, Kohler & Milstein (1975) Nature 256:495-497; Harlow & Lane (1988) Antibodies: a Laboratory Manual, Cold Spring Harbor Lab., Cold Spring Harbor, NY). The genes encoding the heavy and light chains of an antibody of interest can be cloned from a cell, e.g., the genes encoding a monoclonal antibody can be cloned from a hybridoma and used to produce a recombinant monoclonal antibody. Gene libraries encoding heavy and light chains of monoclonal antibodies can also be made from hybridoma or plasma cells. Random combinations of the heavy and light chain gene products generate a large pool of antibodies with different antigenic specificity. Techniques for the production of single chain antibodies or recombinant antibodies (US 4,946,778; US 4,816,567) can be adapted to produce antibodies used in the fusion proteins and methods of the instant invention. Also, transgenic mice, or other organisms such as other mammals, may be used to express human or humanized antibodies. Alternatively, phage display technology can be used to identify antibodies and heteromeric Fab fragments that specifically bind to selected antigens.

Antibody Screening and Selection

[0034] Screening and selection of preferred antibodies can be conducted by a variety of methods known to the art. Initial screening for the presence of monoclonal antibodies specific to a target antigen may be conducted through the use of ELISA-based methods, for example. A secondary screen is preferably conducted to identify and select a desired monoclonal antibody for use in construction of the multi-specific fusion proteins of the invention. Secondary screening may be conducted with any suitable method known to the art. One preferred method, termed "Biosensor Modification-Assisted Profiling" ("BiaMAP") is described in co-pending USSN 60/423,017 filed 01 Nov 2002, herein specifically incorporated by reference in its entirety. BiaMAP allows rapid identification of hybridoma clones producing monoclonal antibodies with desired characteristics. More specifically, monoclonal antibodies are sorted into distinct epitope-related groups based on evaluation of antibody:antigen interactions.

Treatment Population

[0035] The number of people suffering with diabetes mellitus is expected to reach 300 million by

the year 2009 (Type 2 Diabetes Prediction and Prevention (1999) ed. G. A. Hitman, John Wiley & Sons), of which about 80-90% are type 2 diabetes. Diabetic retinopathy is a leading cause of blindness; other complications of diabetes include renal disease, foot problems and neuropathic conditions. In type 1 or insulin dependent diabetes mellitus (IDDM) the insulin-producing B cells of the pancreas are destroyed by what is probably an autoimmune disease. Insulin replacement is the preferred therapy.

[0036] The pathogenesis of type 2 or non insulin dependent diabetes mellitus (NIDDM) has though been determined to result from both a B cell defect and insulin resistance. Thus, patients with type 2 NIDDM have the two physiological defects of hypersecretion of insulin (during the early phase of type 2 diabetes) and resistance to insulin in target tissues. Thus, in the first phase of NIDDM, the plasma glucose level is normal despite demonstrable insulin resistance with elevated insulin levels. In the second phase insulin resistance worsens so that postprandial hyperglycemia develops despite elevated insulin. In the third or late phase of type 2 diabetes, insulin resistance does not change but declining insulin secretion causes fasting hyperglycemia and overt diabetes.

[0037] Disorders associated with insulin resistance include NIDDM, diabetic angiopathy, atherosclerosis, diabetic nephropathy, diabetic neuropathy, and diabetic ocular complications such as retinopathy, cataract formation and glaucoma, as well as glucocorticoid induced insulin resistance, dyslipidemia, polycysitic ovarian syndrome, obesity, hyperglycemia, hyperlipidemia, hypercholesterolemia, hypertriglyceridemia, hyperinsulinemia, and hypertension.

[0038] Accordingly, the population to be treated by the method of the invention are subjects suffering from NIDDM, subjects suffering from insulin resistance, and subjects at risk for worsening of NIDDM or insulin resistance. Further, a subject with one or more symptoms associated with NIDDM is a candidate for treatment by the method of the invention. The diagnosis of a patient at risk for development of NIDDM or suffering from NIDDM is preferably made by a qualified clinician. Methods for diagnosing NIDDM are described, for example, in US 5,719,022, herein specifically incorporated by reference.

Methods of Administration

[0039] The invention provides methods of treatment comprising administering to a subject an effective amount of an agent of the invention. In a preferred aspect, the agent is substantially purified (*e.g.*, substantially free from substances that limit its effect or produce undesired side-

effects). The subject is preferably an animal, *e.g.*, such as cows, pigs, horses, chickens, cats, dogs, etc., and is preferably a mammal, and most preferably human.

[0040] Various delivery systems are known and can be used to administer an agent of the invention, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the compound, receptor-mediated endocytosis (see, *e.g.*, Wu and Wu, 1987, J. Biol. Chem. 262:4429-4432), construction of a nucleic acid as part of a retroviral or other vector, etc. Methods of introduction can be enteral or parenteral and include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, and oral routes. The compounds may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (*e.g.*, oral mucosa, rectal and intestinal mucosa, etc.) and may be administered together with other biologically active agents. Administration can be systemic or local. Administration can be acute or chronic (e.g. daily, weekly, monthly, etc.) or in combination with other agents.

[0041] In another embodiment, the active agent can be delivered in a vesicle, in particular a liposome (see Langer (1990) Science 249:1527-1533). In yet another embodiment, the active agent can be delivered in a controlled release system. In one embodiment, a pump may be used (see Langer (1990) *supra*). In another embodiment, polymeric materials can be used (see Howard et al. (1989) J. Neurosurg. 71:105). In another embodiment where the active agent of the invention is a nucleic acid encoding a protein, the nucleic acid can be administered *in vivo* to promote expression of its encoded protein, by constructing it as part of an appropriate nucleic acid expression vector and administering it so that it becomes intracellular, *e.g.*, by use of a retroviral vector (see, for example, U.S. Patent No. 4,980,286), or by direct injection, or by use of microparticle bombardment (*e.g.*, a gene gun; Biolistic, Dupont), or coating with lipids or cell-surface receptors or transfecting agents, or by administering it in linkage to a homeobox-like peptide which is known to enter the nucleus (see *e.g.*, Joliot et al., 1991, Proc. Natl. Acad. Sci. USA 88:1864-1868), etc. Alternatively, a nucleic acid can be introduced intracellularly and incorporated within host cell DNA for expression, by homologous recombination.

Cellular Transfection and Gene Therapy

[0042] The present invention encompasses the use of nucleic acids encoding the VEGF-specific fusion proteins of the invention for transfection of cells *in vitro* and *in vivo*. These nucleic acids can be inserted into any of a number of well-known vectors for transfection of target cells and

organisms. The nucleic acids are transfected into cells *ex vivo* and *in vivo*, through the interaction of the vector and the target cell. Reintroduction of transfected cells may be accomplished by any method known to the art, including re-implantation of encapsulated cells. The compositions are administered (e.g., by injection into a muscle) to a subject in an amount sufficient to elicit a therapeutic response. An amount adequate to accomplish this is defined as "a therapeutically effective dose or amount."

[0043] In another aspect, the invention provides a method of treating diabetes in a human comprising transfecting a cell with a nucleic acid encoding a VEGF-specific fusion protein of the invention, wherein the nucleic acid comprises an inducible promoter operably linked to the nucleic acid encoding the VEGF-specific fusion protein. For gene therapy procedures in the treatment or prevention of human disease, see for example, Van Brunt (1998) Biotechnology 6:1149-1154.

Combination Therapies

[0044] In numerous embodiments, the VEGF-specific fusion proteins of the present invention may be administered in combination with one or more additional compounds or therapies. Combination therapy includes administration of a single pharmaceutical dosage formulation which contains a VEGF-specific fusion protein and one or more additional hypoglycemic agent or weight loss agent; as well as administration of a VEGF-specific fusion protein and one or more additional hypoglycemic agent or weight loss agent in its own separate pharmaceutical dosage formulation. For example, a VEGF-specific fusion protein of the invention and a hypoglycemic agent can be administered to the patient together in a single oral dosage composition such as a tablet or capsule, or each agent administered in separate oral dosage formulations. Where separate dosage formulations are used, the VEGF-specific fusion protein of the invention and one or more additional hypoglycemic agents can be administered at essentially the same time, i.e., concurrently, or at separately staggered times, i.e., sequentially.

[0045] An examples of such weight loss agents is Axokine® (Regeneron) Examples of such hypoglycemic agents include: insulin; biguanidines, such as metformin Glucophage® (BMS), and buformin; sulfonylureas, such as acetohexamide, Diabinese® (Pfizer), Amaryl® (Aventis), Glynase Pres Tabs® (Pharmacia), Glucotrol XL® (Roering Pfizer), tolazamide, tolbutamide, DiaBeta® (Hoechst), Glucotrol® (Pfizer) and glyclazide; thiazolidinediones, such as Rezulin® (Park Davis), Actos® (Tekada), and Avandia® (GSK); α-glycosidase inhibitors, such as Precose® (Bayer) and Glyset® (Bayer); Meglitinide such as Prandin® (Novo Nordisk); Glucose Elevating Agents such as

Glucagon® (Lilly); and β_3 adrenoreceptor agonists such as CL-316,243.

Pharmaceutical Compositions

[0046] Pharmaceutical compositions useful in the practice of the method of the invention include a therapeutically effective amount of an active agent, and a pharmaceutically acceptable carrier. The term "pharmaceutically acceptable" means approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly, in humans. The term "carrier" refers to a diluent, adjuvant, excipient, or vehicle with which the therapeutic is administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Suitable pharmaceutical excipients include starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. The composition, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. These compositions can take the form of solutions, suspensions, emulsion, tablets, pills, capsules, powders, sustained-release formulations and the like. The composition can be formulated as a suppository, with traditional binders and carriers such as triglycerides. Oral formulation can include standard carriers such as pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, etc. Examples of suitable pharmaceutical carriers are described in "Remington's Pharmaceutical Sciences" by E.W. Martin.

[0047] In a preferred embodiment, the composition is formulated in accordance with routine procedures as a pharmaceutical composition adapted for intravenous, subcutaneous, or intramuscular administration to human beings. Where necessary, the composition may also include a solubilizing agent and a local anesthetic such as lidocaine to ease pain at the site of the injection. Where the composition is to be administered by infusion, it can be dispensed with an infusion bottle containing sterile pharmaceutical grade water or saline. Where the composition is administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

[0048] The active agents of the invention can be formulated as neutral or salt forms. Pharmaceutically acceptable salts include those formed with free amino groups such as those derived from hydrochloric, phosphoric, acetic, oxalic, tartaric acids, etc., and those formed with free

carboxyl groups such as those derived from sodium, potassium, ammonium, calcium, ferric hydroxides, isopropylamine, triethylamine, 2-ethylamino ethanol, histidine, procaine, etc.

[0049] The amount of the active agent of the invention that will be effective in the treatment of diabetes can be determined by standard clinical techniques based on the present description. In addition, *in vitro* assays may optionally be employed to help identify optimal dosage ranges. The precise dose to be employed in the formulation will also depend on the route of administration, and the seriousness of the condition, and should be decided according to the judgment of the practitioner and each subject's circumstances. However, suitable dosage ranges for intravenous administration are generally about 50-5000 micrograms of active compound per kilogram body weight. Suitable dosage ranges for intranasal administration are generally about 0.01 pg/kg body weight to 1 mg/kg body weight. Effective doses may be extrapolated from dose-response curves derived from *in vitro* or animal model test systems.

[0050] For systemic administration, a therapeutically effective dose can be estimated initially from *in vitro* assays. For example, a dose can be formulated in animal models to achieve a circulating concentration range that includes the IC_{50} as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Initial dosages can also be estimated from *in vivo* data, e.g., animal models, using techniques that are well known in the art. One having ordinary skill in the art could readily optimize administration to humans based on animal data.

[0051] Dosage amount and interval may be adjusted individually to provide plasma levels of the compounds that are sufficient to maintain therapeutic effect. One having skill in the art will be able to optimize therapeutically effective local dosages witho ut undue experimentation.

[0052] The amount of compound administered will, of course, be dependent on the subject being treated, on the subject's weight, the severity of the affliction, the manner of administration, and the judgment of the prescribing physician. The therapy may be repeated intermittently while symptoms are detectable or even when they are not detectable. The therapy may be provided alone or in combination with other drugs.

Kits

[0053] The invention also provides an article of manufacturing comprising packaging material and a pharmaceutical agent contained within the packaging material, wherein the pharmaceutical agent comprises at least one VEGF-specific fusion protein of the invention and wherein the packaging

material comprises a label or package insert which indicates that the VEGF-specific fusion protein can be used for treating diabetes.

Other features of the invention will become apparent in the course of the following descriptions of exemplary embodiments which are given for illustration of the invention and are not intended to be limiting thereof.

EXAMPLES

[0054] The following example is put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the methods and compositions of the invention, and are not intended to limit the scope of what the inventors regard as their invention. Efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1: Effect of VEGFR1R2-FcΔC1(a) Treatment in Diabetic *(db/db)* Mice

[0055] Diabetic *(db/db)* mice at 8-10 weeks of age were acclimated for 1 week and treatment began after this point. Groups of *db/db* mice (n=6) were randomly assigned by weight and treated by s.c. injection once a week for 4 weeks with one of the following compositions: carrier (Vehicle); FcΔC1 protein (Fc); or 25, 12.5, or 2.5 mg/kg of VEGFR1R2-FcΔC1(a). Additionally, two groups of non-diabetic *(db/?)* mice were treated by s.c. injection as follows: 25mg/kg of VEGFR1R2-FcΔC1(a) and carrier (Diabetic Vehicle). Blood glucose levels were assessed at the same time each week immediately before the next injection for the 4 weeks of treatment. All groups were assessed at this time by an oral glucose tolerance test. Treatment of animals was continued for a further 4 weeks (8 weeks total) following the regimen described above, and blood glucose levels were assessed after 8 weeks of treatment.

[0056] Results at 4 weeks of treatment. All diabetic *(db/db)* animals had developed hyperglycemia at the staring time of the experiment as shown by the elevated blood glucose (Preface DIA- groups in Fig. 1A at time 0). Animals treated with 25, 12.5 and 2.5 mg/kg VEGFR1R2-FcΔC1(a) showed a significant and progressive reduction in serum glucose over the 8 week treatment period.Animals treated with 25, 12.5 and 2.5 mg/kg VEGFR1R2-FcΔC1(a) did not show a significant reduction in

body weight compared to Vehicle or FcΔC1 control mice over the first 4 week period (repeated measures ANOVA, N.S. see Fig. 1B).

[0057] Results for 8 Weeks of treatment. All diabetic (*db/db)* animals still exhibited hyperglycemia as shown by the elevated blood glucose (Preface DIA- groups in Fig. 2 at time week 8). Animals treated with 25, 12.5 and 2.5 mg/kg VEGFR1R2-FcΔC1(a) showed a significant reduction in serum non fasted blood glucose over the 8 week treatment period (repeated measures ANOVA, d.f. 4, 25, F_{Group}=6.36 p=0.001, F_{Time}=38.5 p<0.0001; $F_{interaction}$=1.8 p=0.04 ; see Fig. 1A).

Example 2: Effect of VEGFR1R2-FcΔC1(a) on Oral Glucose Tolerance in Diabetic Mice

[0058] Diabetic (*db/db)* and non-diabetic (*db/?)* mice mice at 8-10 weeks of age were treated as described above.

[0059] The ability to dispose of a bolus of glucose delivered into the stomach by gavage was assessed after 4 injections (week 5) and after 8 injections (at week 9). For this assessment, mice are deprived of food for approximately 18 hours and after being gavaged, blood glucose was measured at 0, 30, 60 and 120 min.

[0060] Results for 4 weeks of treatment. Vehicle and FcΔC1 protein treated diabetic (*db/db)* mice had an impaired ability to dispose of glucose compared to lean non-diabetic (*db/?*) control mice (Fig. 3). After 4 injections (in the 5th week) animals treated with 25, 12.5 and 2.5 mg/kg VEGFR1R2-FcΔC1(a) showed a significant improvement in the ability to dispose of the administered glucose. These results demonstrate that VEGF inhibition improves glucose tolerance in diabetic mammals. In contrast, the Vehicle and FcΔC1 protein treated diabetic (*db/db)* mice show no improvement in the ability to dispose of glucose or glucose tolerance (Fig. 3).

[0061] Results for 8 weeks of treatment. Vehicle and FcΔC1 protein treated diabetic (*db/db)* mice still had an impaired ability to dispose of glucose compared to lean non-diabetic (*db/?*) control mice (Fig. 4). After a total of 8 injections (in the 9th week) animals treated with 25, 12.5 and 2.5 mg/kg VEGFR1R2-FcΔC1(a) showed a significant improvement in the ability to dispose of the administered glucose. These results demonstrate that VEGF inhibition improves glucose tolerance in diabetic mammals. In contrast, the Vehicle and FcΔC1 protein treated diabetic (*db/db)* mice show no improvement in the ability to dispose of glucose or glucose tolerance (Fig. 4).

Example 3. Effect of VEGFR1R2-FcΔC1(a) Treatment on Fasting Serum Glucose and Insulin in Diabetic (*db/db)* Mice

[0062] Diabetic (*db/db)* mice were acclimated for 1 week and treatment began as described above. After 8 injections (in the 9th week) fasting blood glucose and insulin (Fig 5B) was assessed.

[0063] Vehicle and FcΔC1 protein treated diabetic (*db/db)* mice had elevated fasting blood glucose levels compared to lean non diabetic (*db/?*) control mice (Fig. 5A). VEGFR1R2-FcΔC1(a)-treated animals showed a significant reduction in fasting serum glucose compared to diabetic controls (Vehicle or FcCΔ1; Fig 5 A) and a significantly reduced insulin level. This demonstrates that VEGF inhibition improves not only hyperglycemia in a diabetic mammal but also improves insulin sensitivity.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof.